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SOME SOIL FACTORS AFFECTING TREE GROWTH[1]

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IT is just one hundred years since Liebig, in his famous report to the British Association upon the state of organic chemistry, delivered with vitriolic invective the death sentence to the theory held by contemporary plant physiologists that plants obtain their carbon from the soil. He did it in these words, "All explanations of chemists must remain without fruit, and useless, because, even to the great leaders of physiology, carbonic acid, ammonia, acids and bases are sounds without meaning, words without sense, terms of an unknown language, which awaken no thoughts and no associations." How different is the state of affairs to-day, how ramshackle have become the once hallowed walls dividing the natural sciences, must be apparent when an agronomist deigns to rise before a group of horticulturists and foresters and speak on a program dealing with the physiological aspects of tree growth. Fortunately it appears now well established that both fruit and forest trees send their roots into the soil, that natural medium which until recent times was peculiarly the domain of the agronomist. Fortunately, also, the interactions of the soil and tree appear not to differ materially from the interactions of the soil and agronomic crops. In fact, except in the degree of surface manipulation involved and in the

[1] Address of the retiring vice-president and chairman of the Section on Agriculture, American Association for the Advancement of Science, Columbus, Ohio, December 30, 1939.

proportion of extracted soil constituents and residues returned, there exist no major differentials in the plant-soil relationships of trees and field crops. Accordingly, it may not be inappropriate for one who thinks chiefly in terms of the latter to discuss soil factors affecting tree growth.

This is obviously not the place to attempt a résumé of the extensive literature dealing with soil-tree relationships. Instead, therefore, I have chosen to present a rather generalized picture of certain root-soil relationships, especially those affecting the availability of water, oxygen and soil nutrients, as visualized in the light of recent researches in soil physics and soil chemistry. Acting within the prerogatives of this kind of a talk, this will be done with high disregard of the usual necessity for giving credit to individuals. Mention of some names will be inescapable.

Physical Make-up of the Soil

Let us picture first the soil as a physical body. It has a frame-work of rock particles, composed of primary minerals and ranging in size from small stones to particles of colloidal dimensions. However, few primary minerals occur in sizes below 0.002 mm diameter, which represents approximately the upper size limit of a second important group, the secondary clay minerals, the chief colloidal components of mineral soils. The latter are mainly hydrated alumino-silicates with varying admixture of hydrated oxides of iron and aluminum. These clay particles usually have a plate-like crystalline structure. Two fundamental types are recognized. One, the so-called montmorillonite type, characteristic of weathering in temperate climates, possesses an expansion joint in its crystal lattice which expands and shrinks with varying hydration and contributes enormously to the amount of reactive surface exposed. These clays exhibit in marked degree such colloidal properties as swelling and shrinking, cohesion and plasticity. Moreover, they are active chemically, being able to hold on their surfaces, through electrostatic forces, not only water molecules but considerable amounts of cations, and to a lesser extent anions, especially the phosphate anion. The second type, the so-called halloysite type, characteristic of tropical weathering, possesses no expansion joint in its crystal lattice, and, presumably because of lower specific surface, exhibits the previously mentioned colloidal properties in much lower degree. However, since such clays often carry much hydrated iron and aluminum, they frequently show high phosphate fixing power. Included in the solid body of the soil, but largely concentrated in the upper horizons in the case of mineral soils, is the soil organic matter or humus. Although comprising materials in all stages of chemical and physical degradation, the most important fraction from the standpoint of soil properties is the colloidal humus. The latter represents an advanced stage of biochemical degradation, is mainly composed of lignin combined with microbial protein, contains carbon and nitrogen in nearly constant ratio, usually between 8 and 12, is fairly resistant to further biological attack, and exhibits in exaggerated degree most of the colloidal properties shown by montmorillonitic clays.

Soil Structure

Except in coarse-textured soils low in colloidal components, the arrangement of the solid soil particles is seldom haphazard. The finer particles tend to occupy interstices between the larger, and the very fine colloidal clay and humus particles frequently occur as coatings on the larger particles, where, owing to their hydrated character, they serve to bind the particles together into various types of structural units. In the surface horizons where alternate wetting and drying or freezing and thawing occur, and which contain the major part of the soil humus, and of the plant roots and micro-organisms, the structural units formed are mostly irregular rounded granules, whose stability varies widely, but usually increases with increasing humus content and especially with increasing activity of plant roots and micro-organisms. In the lower soil horizons within the zone of weathering, structural units also develop, usually blocks which may be cubical, columnar or prismatic in shape, bounded by cleavage planes or cracks.

Soil Pore Space

That part of the total soil volume not occupied by solid particles, *i.e.*, the pore space, is obviously the direct complement, both in extent and geography, of the solid phase. The greater the volume of solid material within a given volume of soil, the smaller is the total pore space, hence the existence of a general inverse relation between pore space and volume weight. Corresponding to the multiplicity of shapes, sizes and arrangements of the solid particles is a similar multiplicity of shapes, sizes and arrangement of the individual pores. No simple concept such as that of a series of continuous capillary tubes of uniform cross-section can be applied to the soil-pore space, although such a picture does fit fairly well the larger pores formed by structural cleavage planes, and pores left by decaying plant roots, or formed by the burrowing of worms, insects, etc. The great bulk of the pore space is probably better pictured as angular-shaped cells connected in hit-or-miss fashion by small irregular openings. Although recent techniques for the direct microscopic study of soils, both en masse and in thin section, have added to our knowledge of soil structure and pore-space geography, no direct procedures are available for characterizing the latter. Hence, it has been necessary to resort to indirect meth-

ds, the most useful being the measurement of the mounts of water held by a soil at varying moisture nsions imposed by suction, centrifuging and in the rier ranges by reducing the vapor tension. Such easurements indicate that, depending chiefly on tex- re and structure, soils vary widely in the size distri- ution of their effective pore sizes, such variations eing commonly much greater than variations in the otal volume of pore space. Moreover, there often ecur wide differences in pore-size distribution among he different horizons making up a given soil profile. These differences, both between soils and soil horizons, re of greatest significance in determining the availabil- y of both air and water to plant roots.

Soil Moisture

Under natural conditions the retention and move- ent of water in soils is controlled by several different orces, including molecular attraction at the solid sur- aces, surface tension at the liquid-air interfaces, ravity and hydrostatic forces. Much attention re- ently has been given to measuring the energy with which water is held by soils at different moisture ontents. By proper choice of method, it is possible o relate moisture content and energy potential hroughout the complete moisture range from dryness o saturation. For example, vapor pressure, freezing oint, centrifuge and tensiometer methods find adapta- ion in the order named as one passes from the region of high potentials and low-moisture contents to the region of low potentials and high-moisture contents. The results obtained have contributed greatly to our knowledge of the use of water by plants, of soil mois- ture movement and of the way water is held in the soil. The curves relating potential and moisture content are hyperbolic in type with no apparent discontinuities, the latter fact indicating that the older classification of soil water into hygroscopic, capillary and gravita- tional is largely arbitrary. A variation in the method of plotting potential against moisture content intro- duced by Schofield[2] consisted in plotting the common logarithm of the moisture-tension, expressed as cm of water and designated as pF, against the moisture per- centage. This method permits increased refinement of interpretation in the lower potential range correspond- ing to moisture contents from saturation to the wilting point and including the full moisture range in which movement of water in the liquid phase normally occurs.

In a saturated soil with the normal pore space, the moisture tension approximates zero ($pF = -\infty$), little or no force being required to extract the first increment of water from it. If such a soil is permitted to drain under gravity, the moisture tension increases as the moisture content decreases down to a certain point at which water ceases to be lost, the so-called "field capacity" of the soil, or point of "zero capillary permeability." At this point according to Richards[3] the water is no longer present in a continuous liquid film and any water translocation must take place in the vapor phase. This point is ordinarily considered to be about pF 3 and approximately coincident with the moisture equivalent. However, recent work by Moore[4] indicates that it is nearer pF 2.0 and tends to vary with texture, being highest with fine textured soils. Moisture held at "field capacity" is readily utilized by plants. It represents the upper limit of the available water range, except when water is actually moving down through the soil, as after a rain, or when the root zone extends to within a relatively short distance of a free water table. The content of moisture held against gravity, *i.e.*, the field capacity, tends to increase exponentially with decreasing particle size, hence tends to be many times higher in clay soils than in sandy soils, and also increases with the amount of humus present.

Availability of Water to Plants

It now seems fairly well established that plants can utilize water down to a tension of about pF 4.2, corresponding to an osmotic pressure of about 16 atmospheres, before complete wilting occurs, providing the soil is thoroughly permeated with roots and the rate of transpiration is low. This point has been designated as the "wilting point" or "wilting coefficient," and like the "field capacity" varies with soil texture and soil structure and apparently little or none with the kind of plant. On the other hand, there exist differences of opinion regarding the ease with which water above this point is utilized. Veihmeyer and Hendrickson,[5, 6] from studies with prune and peach trees, concluded that between field capacity and the wilting point there was no difference in the availability of soil water, that the wilting point is a critical soil moisture content, and that the trees either have readily available water or have not. There is considerable work opposed to this idea and indicating that entrance of water may become so restricted as to cause cessation of fruit growth—at least with pears, apples and citrus—and even incipient wilting of leaves at moisture contents considerably above the point of complete wilting. The idea of a "wilting range" has been suggested as better fitting the facts than a single "critical wilting point." A difficulty inherent in all this work is the inability to measure the moisture content of the soil immediately in contact with the root. If we accept the idea that there

[2] R. K. Schofield, *Trans. Third Inter. Cong. Soil Sci.*, 2: 38–48, 1935.

[3] L. A. Richards, *Jour. Amer. Soc. Agron.*, 28: 297–306, 1936.

[4] R. E. Moore, *Hilgardia*, 12: 383–426, 1939.

[5] F. J. Veihmeyer, *Hilgardia*, 2: 125–284, 1927.

[6] A. H. Hendrickson and F. J. Veihmeyer, *Calif. Agr. Exp. Sta. Bul.*, 479: 1–56, 1929.

is no appreciable movement of water by capillarity at moisture tensions below that at "field capacity," and this idea seems well founded, also the equally probable idea that movement of water in the vapor phase is too slight to be a factor (at 20° C., the relative humidity at pF 3.0 is 99.3 and at pF 4.2, 95.5), then it must follow that only as roots come directly in contact with hitherto untouched soil-moisture films can enough water be obtained to replace that lost in transpiration. The vital necessity for the rapid and continuous extension of root systems of transpiring plants has recently been pointed out by Kramer,[7] who states the belief that "when environmental conditions favor rapid transpiration, cessation of root-extension for only one or two days would result in death of many, and possibly most plants, from desiccation." He also calls attention to the work of Pavlychenko,[8] indicating that the number of growing root tips is extremely large and their extension must amount to many feet or, in the case of large plants, to hundreds of yards daily. Further, he states, "the roots of many plants are completely suberized when root extension ceases."

From the foregoing it is evident that the ability of trees to resist drouth will depend not only on the amount of available water held by the soil, *i.e.*, the spread between field capacity and wilting point, but, equally important, upon the volume of soil permeated by roots and the presence or absence of impediments, either mechanical or physiological, to rapid root extension. Obviously also, the frequency and ease of renewal of the available water in areas desiccated by root absorption through the processes of infiltration and percolation may be highly important.

The capacity of a soil to hold water within the available tension range is relatively insensitive to structural changes, although compaction tends to increase it somewhat, unfortunately, however, at the expense of permeability to air and water. Hence, although coarse-textured soils may benefit from compaction, medium- to fine-textured soils are more likely to be injured. The well-known effect of organic matter additions in increasing moisture held at field capacity appears, on the basis of recent studies, not to involve any similar effect on the amount of available water, since the wilting percentage is also increased in approximately equal degree.

Permeability of Soils to Water

The adequacy of soil moisture for growth and survival may depend as much upon frequency of renewal by rain or irrigation and upon the ability of the soil to absorb water—the infiltration capacity—as upon the capacity of the soil as a water reservoir. From a study of the growth of apples in relation to soil moisture in ten New York orchards in 1936 and 1937, Boynton and Savage[9] infer that, although available water capacity is probably the most important soil factor determining the availability of water in the case of shallow soils, the infiltration capacity may be the most important factor with heavy soils. Moreover, the drainage of excess water from a soil is also dependent upon those properties which determine the rate at which water moves through a soil under the force of gravity. Hence permeability to water ranks high among soil factors determining the site quality for tree growth.

Permeability to water depends both upon the amount and size distribution of the pore space in a soil. Assuming an idealized cylindrical pore in a saturated soil with no impediment to drainage, the amount of water transmitted by gravity under constant head should be a direct function of its cross-section and an inverse function of its surface, which retards flow through frictional stress. Since the amount of surface per unit cross-section varies inversely with pore diameter, it follows that the amount of water transmitted per unit of total pore volume will be larger with large than with small pores. A useful concept originally introduced by Schumacher in 1864,[10] divides the pore space in a soil into two categories. In modern terminology these may be characterized as (1) pores still completely filled with water at "field capacity," designated as "capillary pores" and (2) pores containing varying amounts of air under the same conditions, designated as "non-capillary pores." Capillary pore space is considered the chief reservoir for water held against gravity, whereas movement of water through a soil takes place chiefly through the non-capillary pore space. Although two soils having the same total non-capillary pore space will not necessarily transmit water with equal facility, owing to variations in the size distribution of the non-capillary pores, recent studies by Baver[11] upon a widely diverse group of soils indicate that the amount of non-capillary pore space of a soil is in general a fairly good criterion of its permeability. Moreover, the relation of permeability to non-capillary porosity appears to be exponential, the former tending to increase somewhat faster than the square of the latter. Thus a soil with 10 per cent. of non-capillary porosity will have a permeability more than four times as great as one with 5 per cent. and more than 25 times as great as one with 2 per cent. of non-capillary porosity. Another important fact shown in Baver's work is that compaction of a soil tends to reduce the non-capillary porosity relatively much more than the

[7] P. J. Kramer, "Transactions American Geophysical Union, 1937." Part II, p. 313. National Research Council, Washington, D. C., July, 1937.

[8] T. K. Pavlychenko, *Ecol.*, 18: 62–79, 1937.

[9] D. Boynton and E. F. Savage, *Cornell Univ. Agr. Exp. Sta. Bul.*, 706: 1–36, 1938.

[10] Schumacher, "Die Physik," Weygandt, Berlin, 1864.

[11] L. D. Baver, *Proc. Soil Sci. Soc. Amer.*, 2: 52–56, 1938.

otal pore space. For example, compaction of a Cecil ay to a point where it had lost about 10 per cent. of s original total pore space, reduced its non-capillary orosity 60 per cent.

In contrast to the "capillary porosity" and "field apacity" of a soil, non-capillary porosity is enorously influenced by variations in soil structure. The ffect of compaction has already been noted. Granuation is highly effective in increasing the non-capillary orosity of fine-textured soils, likewise the addition of rganic matter. In lysimeter studies at Clarinda, Iowa, Musgrave and Norton[12] showed that the amount of ater percolating through Marshall silt loam was inreased 54 per cent. and through Shelby silt loam 135 er cent. by the incorporation of 16 tons of manure er acre. Continuous pores left in the soil by the ecay of plant roots or by the burrowing of small nimals may contribute greatly to the permeability of oils, especially under forest conditions, but often to n important extent in pasture and field soils. The bnormally high rates often found in infiltration studies n forest soils are thus explained. Deterioration in ite quality for trees of land once in forest after tilization for cropping or pasture for a period of ears is probably due in part to the disappearance of hese biotic channels, although loss of humus and ases and decreased granulation may also be involved. nother factor affecting non-capillary porosity is the endency of soil colloids, both clay and humus, to swell hen wetted, the effect being to transform a part of he non-capillary porosity into capillary porosity. A sser tendency to hydrate and swell probably explains he relatively high permeability of certain tropical ay soils compared to humid temperate soils of equally ne texture. Although the colloids in the soil profile re usually fully hydrated, except in the upper few nches of surface soil the swelling of the colloids in his layer after a rain may decrease materially the on-capillary porosity of a fine-textured soil or one igh in organic matter.

The old adage that "a chain is no stronger than its eakest link" applies to the movement of water hrough the soil profile. In other words, the transmision characteristics of the profile are determined by he permeability of the least permeable horizon. The resence of even a thin horizon of impermeable soil ay block rather completely the drainage of a soil hich otherwise would be well drained. Thus it is ecessary to recognize that soils possess a "permeabilty profile" corresponding to their textural and struc ral profiles. This is especially important in the emperate humid region where it is normal to find a eavy layer in the upper subsoil, notably in poorly rained light-colored soils, the so-called "clay pan soils." A very important factor in decreasing the infiltration of rainwater on soil unprotected by vegetative cover is the decrease in non-capillary porosity of the soil at the immediate surface, resulting chiefly from the mechanical impact of raindrops destroying granulation, an effect facilitated by the accompanying removal of electrolytes and hydration of the colloids. This effect is almost completely prevented by dense growing vegetative cover or by a layer of surface litter.

[12] G. W. Musgrave and R. A. Norton, United States Department of Agriculture, *Tech. Bul.*, 558: 1–182, 1937.

Mineral Uptake

It has already been pointed out that continued intake of water by the plant necessitates the continuous extension of the absorbing roots to provide fresh contacts with unexhausted moisture films. Recent studies have suggested that root-soil contact may be equally important to the intake of mineral elements. It is now generally recognized that, although the weathering of primary minerals is necessary to the maintenance of adequate available supplies of such mineral elements as potassium, calcium, magnesium, etc., the process is generally too slow to take care of the requirements of rapidly growing vegetation. Instead, the immediate reservoir of available mineral elements appears to be the ions held by electro-static forces on the surfaces of the soil colloids. A small proportion of the ions so held (Mattson[13] estimates of the order of 0.2 per cent.) enter the film water bathing the colloid from which they may be taken in by the plant root. The distribution of any given ion between the soil solution and the colloid being in the nature of a highly mobile equilibrium, continuous renewal of any ions taken up is to be expected. There is no reason to doubt but that the mechanism just described does contribute to the mineral nutrition of the plant. On the other hand, it has recently been suggested by Jenny and Overstreet[14] that it may not be the sole mechanism nor necessarily the most important one. Aside from the fact that the concentration of most nutrient ions, as judged from displaced soil solution studies, is so low even in fertile soils as to require a very large number of complete replacements to account for the total intake by plants during the growing season, the concentrations of certain ions (*viz.*, the PO_4 ion) are frequently considerably below the concentrations found in flowing solution culture studies to be necessary for satisfactory growth. Parker[15] found practically no phosphorus in the displaced solution from a soil which normally produced a fairly satisfactory yield of corn without phosphate fertilization. By exposing the roots of plants to suspensions of mineral colloids saturated either with hydrogen or basic cations, Jenny and Over-

[13] Sante Mattson, *Jour. Agr. Res.*, 33: 553–567, 1926.

[14] H. Jenny and R. Overstreet, *Soil Sci.*, 47: 257–273, 1939.

[15] F. W. Parker, *Soil Sci.*, 24: 129–146, 1927.

street have succeeded in demonstrating what they consider to be a direct surface exchange of ions between the root and the colloid. Employing the hydrogen saturated colloid, hydrogen ions are apparently absorbed by the root and equivalent amount of K, Ca, Mg, etc., released by the root to the colloid. When a potassium saturated colloid is employed, potassium seems to be absorbed by the root in exchange for hydrogen ions. Translating these observations to soil conditions, it is suggested that the carbon dioxide produced by respiration within the root cell combines with the water forming carbonic acid which diffuses through the cell wall, on the outer surface of which a certain number of H^+ and HCO_3^- ions produced by dissociation are held electrostatically. Whenever the root surface lies sufficiently close to a colloidal clay surface that the "oscillation space" of an H^+ ion on the root overlaps with the "oscillation space" of a cation held on the clay, a direct interchange may take place. The same type of exchange may take place between an HCO_3^- ion on the root and an anion held on the clay. Should this idea of direct contact nutrition be substantiated by further work, the desirability of extensive root soil contact may be found as necessary for mineral nutrition as for water absorption.

Soil Factors Affecting Root Growth

The apparent importance of expanding root-soil contact to the intake of water and probably also of mineral nutrients, emphasizes the significance of factors that either favor or impede the direction and extent of root development. It must be admitted that present knowledge is wholly inadequate for a full understanding of the effect of individual factors or of their interactions. There is evidence for believing, however, that under conditions of limiting moisture supply roots will develop toward a positive moisture gradient. Similarly, under conditions of poor aeration, growth will take place toward a negative CO_2 gradient or a positive O_2 gradient. The foregoing relations probably explain the deep rooting of certain field crops in Nebraska as observed by Weaver[16] and the comparatively shallow rooting of the same crops as observed by Farris[17] in New Jersey, also similar differences between fruit trees in Utah, as observed by Ballantyne,[18] and in New York, as observed by Oskamp and Batjer.[19] There is also evidence that roots may develop in response to a favorable nutrient gradient. For example, Bushnell[20] caused potatoes to develop deeper root systems by incorporating phosphorus and nitrogen fertilizers in the subsoil. It is also possible that roots may be prevented from occupying a zone of fine-textured densely packed soil by mechanical impedance. Braun-Blanquet[21] states that if soil grains are less than 0.02 mm in diameter, root hairs are no longer able to penetrate through the spaces between them if the soil has a single grain structure, also that "raw clay" with a grain diameter of less than 0.002 mm will stop the movement even of bacteria. Although little is known regarding the interaction of the factors affecting root growth, it may be postulated that most rapid extension will occur when all the gradients in a given direction are favorable, also that a favorable gradient in one direction may be offset by an opposing unfavorable one. Thus roots may be prevented from occupying a zone of favorable nutrient supply because of a limitation of oxygen. In some cases there appears to exist a mechanism for internal adjustment which neutralizes the effect of an unfavorable gradient if some portion of the root system is developing under more favorable conditions. Thus, the normally deep-rooted crop, alfalfa, will not send its roots through a lime-deficient acid subsoil in response to a favorable moisture gradient except as an abundance of lime is supplied to some part of the root system. In the light of Jenny and Overstreet's[22] work, it would be interesting to determine whether under the latter condition, lime moves from the roots into the adjacent layers of acid soil. It seems possible that a similar mechanism may explain the ability of certain plants to send their roots into soil zones having extremely low oxygen and correspondingly high carbon dioxide contents.

Soil Aeration

Quantitative studies of the distribution within the soil profile of the roots of both fruit and forest trees in humid regions show a general tendency for the roots to be concentrated in the upper soil horizons, also for rooting to be sparse in dense horizons of fine textured soil, usually characterized by a gray or mottled color associated with the presence of reduced iron. These facts suggest that aeration may be a highly important factor in determining root distribution in such regions. Obviously, its importance will be greatest in fine-textured soils with naturally poor drainage.

Respiration is a necessary activity of all living plant roots and soil micro-organisms. Hence removal of oxygen from the soil atmosphere and its replacement by carbon dioxide goes on continually at a rate depending upon the number of roots and micro-organisms present and the favorableness of growth condi-

[16] J. E. Weaver, "Root Development of Field Crops." McGraw-Hill, New York, 1926.

[17] N. F. Farris, *Soil Sci.*, 38: 87–111, 1934.

[18] A. B. Ballantyne, *Utah Agr. Exp. Sta. Bul.*, 143: 1–15, 1916.

[19] Jos. Oskamp and L. P. Batjer, *Cornell Univ. Agr. Exp. Sta. Bul.*, 550: 1–45, 1932.

[20] J. Bushnell, *Amer. Potato Jour.*, 14: 78–81, 1937.

[21] J. Braun-Blanquet, "Plant Sociology" (Trans. by G. D. Fuller and H. S. Conard). McGraw-Hill, New York, 1932.

[22] H. Jenny and R. Overstreet, *loc. cit.*

tions such as temperature, moisture and nutrients, including organic matter in the case of heterotrophic organisms as well as upon the partial pressure of oxygen. In the absence of free gaseous exchange between the soil and the atmosphere, there develops an increasing oxygen deficit and carbon dioxide excess in the soil air, readily reaching a point where root growth is inhibited or prevented. According to Lundegårdh[23] plants are more sensitive to the presence of carbon dioxide than to the absence of oxygen, although large differences exist among plants in their reactions to both factors. These facts are supported by the tabular summary of existing data on critical oxygen and carbon dioxide concentrations given by Romell.[24] Lundegårdh states that the growth of most mesophilous plants begins to fall off when the concentration of carbon dioxide reaches 1 per cent. This figure appears low in view of certain data in Romell's summary, *i.e.,* that restrictions of root growth of beans begins at 2–4 per cent., of vetch at 3 per cent. and of peas at 5 per cent. Little specific information appears to be available on the CO_2 tolerance of tree roots.

It appears well established that gaseous diffusion accounts for practically all the exchange of CO_2 and O_2 between the soil and the atmosphere. Movement of air either into the soil or out of it resulting from pressure gradients produced by temperature differentials, changes in barometric pressure, air movement over the surface soil or even the tendency of water draining into a soil to replace the soil air contribute in very minor degree to the renewal of the soil atmosphere.

With a given gradient in CO_2 and O_2 concentration, the rate of diffusion is a function of the total volume of free pore space, *i.e.,* that not filled with water. In contrast to permeability to water the size distribution of the pore space appears to have no effect on the rate of gaseous diffusion. Hence, in soils having equal amounts of free pore space, differences in texture or structure exert no influence. Under natural conditions, however, pore-size distribution does affect aeration in a most important manner, *i.e.,* in determining what fraction of the total volume will be filled with water under given conditions of rainfall, drainage and use by plants. Since at those times of the year and in those regions of the soil where poor aeration is likely to limit root growth, the capillary pores usually will be filled with water, it follows that the non-capillary porosity will be most effective in contributing to soil aeration.

The excellent early work of Buckingham[25] led him to conclude that the rate of gaseous diffusion through soils varies directly with the square of the free pore space. Although Romell[26] has questioned his interpretation of the data, and the constancy of the foregoing relation, in the absence of more precise data, it may at least serve as a basis for speculation. For example, assuming that diffusion varies as the square of the free pore space, one inch of soil with only 5 per cent. of free pore space will offer as much resistance to CO_2 and O_2 interchange as 25 inches of soil having a free pore space of 25 per cent. Employing Buckingham's method for calculating the CO_2 concentration gradient from the porosity and amount of CO_2 released to the atmosphere per unit area in unit time, and assuming that the latter value is equal to 0.4 gm CO_2 per sq. meter per hour (Romell[27] states that average values for forest soils lie between 0.2 and 0.7 gm), given a free pore space of 25 per cent., the contents of CO_2 in the soil air at 1′, 2′ and 4′ at equilibrium will be 1.63 per cent., 3.26 per cent. and 6.52 per cent., respectively. If now we assume that the upper two inches of the same soil has been compacted or puddled so that its free pore space is only 5 per cent., then the concentration immediately below this layer will be 6.8 per cent., or slightly higher than that at the 4′ depth in the uncompacted soil. Free pore space values of the order of 5 per cent. or even less are not uncommon in poorly granulated fine-textured soils or in the heavy layers which frequently underlie coarser-textured surface soils in the humid region. The example cited serves to show how very important even thin horizons of dense soil may be in reducing aeration and thereby limiting root growth. The effect of such a heavy layer will be influenced by its position with regard to the distribution of CO^2 production in the soil. Romell[28] points out that since most of the CO_2 is produced in the upper one or two feet of soil, an impervious layer at the immediate surface is likely to be most detrimental, since it tends to make the entire profile unfavorable to root growth.

Any consideration of root distribution of trees in relation to soil aeration is limited by the paucity of direct experimental information. Even such measurements as have been reported on the CO_2 content of soil air probably do not represent the composition of the air at the immediate disposal of the growing root tips where higher concentrations of CO_2 may be expected than in samples obtained by merely pushing a tube into a soil to the desired depth and withdrawing a certain volume of air, the usual technique. The existence of a "second atmosphere" in the soil was recognized by Russell and Appleyard,[29] who found that,

[23] Hendrik Lundegårdh, "Environment and Plant Development." Edward Arnold and Company, London, 1931.

[24] L. G. Romell, *Soil Sci.,* 34: 161–188, 1932.

[25] E. Buckingham, United States Department of Agriculture, Bureau Soils, *Bul.,* 25: 1–52, 1904.

[26] L. G. Romell, *Meddel. Statens Skogsförsöksanst* (Sweden), 19: 125–359 (Swedish with German summary).

[27] L. G. Romell, *Soil Sci.,* 34: 161–188, 1932.

[28] *Ibid., Meddel. Statens Skogsförsöksanst* (Sweden) 19: 125–359.

when placed under vacuo, soils released considerable gas, consisting mainly of carbon dioxide with some nitrogen and almost devoid of oxygen. This gas was believed to be held by the soil "dissolved in the surface films of water and other substances." On the other hand, the first portion of gas thus removed contained in several instances nearly as much nitrogen as atmospheric air, hence it seems doubtful that it was present in dissolved form. Instead, it probably came from the smaller pores and more poorly ventilated portions of the soil. Thus, although "free air" samples taken at 6″ depth on an area known as the "Broadbalk wilderness" contained generally less than 0.8 per cent. CO_2 and more than 19.6 per cent. O_2, the first 30 cc of gas removed under vacuo from 400 grams of the same soil contained 19.3 per cent. CO_2 and only 5.5 per cent. O_2, along with 75.2 per cent. N_2. It would appear that much more refined techniques, possibly of a "micro" character, will need to be developed before the actual conditions at the immediate surface of the growing roots will be known.

Root Respiration and Mineral Nutrition

The vital role of root respiration in the physiology of the plant is emphasized by recent work of Hoagland and Broyer,[30] who showed that salt intake by roots tends to vary directly with the intensity of root respiration. Previous work by other investigators had strongly indicated that such a relation between respiration and electrolyte accumulation applies generally to living plant cells. For example, Steward[31] found that it applied to potato tuber tissue and voiced the opinion that respiration "supplies the energy necessary for salt absorption against a concentration gradient as well as the maintenance of existing concentrations of solutes in the vacuole much greater than in the surrounding medium," also that "other variables being adequately controlled, any treatment which either decreases or increases the total respiration . . . causes a corresponding decrease or increase in the total salt absorbed." Not only may respiration supply the energy required to move electrolytes from the normally low concentrations in the soil solution to the relatively high concentrations in the root cells, but also, considered from the viewpoint of Jenny and Overstreet's[32] theory of "contact nutrition," respiration also supplies the H^+ and HCO_3^- ions which the root exchanges for cations and anions on the surface of soil colloids.

Summary

(1) It becomes increasingly evident that continued root growth with the establishment of new root-soil contacts is necessary for the normal entrance of both water and mineral nutrients into the root. This concept emphasizes the ecological importance of factors tending either to impede or favor the spread and permeation of roots in the soil.

(2) The characteristics of soils with respect to (1) available water capacity, (2) permeability to water and (3) permeability to air are largely determined by the volume and size distribution of the soil pore space. The latter is conveniently characterized by measuring the water held by a soil at varying moisture tensions.

(3) In recognition of the foregoing, it may be concluded that a better understanding of root-soil relationships should result from more general application of interpretative studies of soil pore space conditions to root development, and from the development and application of micro-methods for studying the conditions, both physical and chemical, existing at the actual root-soil interface.

[29] E. J. Russell and A. Appleyard, *Jour. Agr. Sci.*, 7: 1–48, 1915.

[30] D. R. Hoagland and T. C. Broyer, *Plant Physiol.*, 11: 471–507, 1936.

[31] F. C. Steward, *Protoplasma*, 17: 436–453, 1932.

[32] H. Jenny and R. Overstreet, *Soil Sci.*, 47: 257–273, 1939.

SCIENTIFIC EVENTS

MATHEMATICAL SYMPOSIUM AT THE UNIVERSITY OF NOTRE DAME

A SYMPOSIUM on the Foundations of Topology was held at the University of Notre Dame on April 10 and 11.

In the classical topology, the concept of space was introduced as a set of points for which certain relations are defined which distinguish the space from an abstract set, *e.g.*, it was assumed that a limit concept has been defined in the space or that neighborhoods of points are given. A recent trend of topology seems to lead away from this set theoretical foundation, and points in the direction of a foundation on relations between the subsets of the space rather than between the points. The points, in this new approach, are introduced only later as certain sequences or systems of subsets of the space.

At the first of the three meetings of the symposium, conducted by Professor S. Lefschetz, of Princeton University, Professor R. L. Moore, of the University of Texas, spoke on "Contiguous Points," a theory somewhat intermediate between the set theoretical foundation and a theory of lumps. Professor Karl Menger, of the University of Notre Dame, developed a theory in which points are defined as certain nested sequences of lumps, a procedure similar to that of physics.

At the morning meeting on Thursday, Professor

E. W. Chittenden, of the University of Iowa, spoke about the "Classification of Topological Functions," connecting the foundations of topology with the so-called lattice theory. Dr. John W. Tukey, of Princeton University, spoke about "The Equal Generality of 'Convergence,' 'Closure' and 'Neighborhoods,'" pointing out the equivalence of the three classical foundations of topology, provided that they are taken in a sufficiently general sense. Dr. A. N. Milgram, of the University of Notre Dame, presented a paper, entitled, "Partially Ordered Sets and Topology," in which he succeeded in deriving important parts of classical topology for general partially ordered sets without any assumption about the existence of points. Professor G. B. Price, of the University of Kansas, conducted a discussion.

In the afternoon meeting on Thursday, conducted by Professor W. L. Ayres, of the University of Michigan, Professor S. Lefschetz spoke on "The Foundations of Algebraic Topology." This theory, started by Poincaré, is of an entirely combinational character. Dr. Henry Wallman, of the Institute for Advanced Study, spoke on "Lattices and Connectivity," first presenting some recent ideas of J. W. Alexander and then his own introduction of topological spaces on the basis of the theory of lattices which he developed in continuation of the work of M. H. Stone.

The meeting was attended by a group of more than forty visitors.

KARL MENGER

CENTENNIAL CELEBRATION OF THE FOUNDING OF THE DEPARTMENT OF CHEMISTRY OF WESTERN RESERVE UNIVERSITY

WESTERN RESERVE COLLEGE was founded at Hudson, Ohio, in 1826, and in the early years chemistry was taught only as a part of other courses. It was not until the college year 1839–40 that a professor began service who taught a course wholly devoted to chemistry. This course was given for one term of the senior year.

The centenary of this event has just been celebrated at the university in Cleveland on Open House Day, April 12. In 1882 the college moved to Cleveland, and at the same time its name was changed to Western Reserve University. Samuel St. John was appointed by the trustees as professor of chemistry, mineralogy and geology and took up his duties in the fall of 1839. He was a graduate of Yale College of the class of 1834. After graduation he remained in New Haven for two years, studying law, and was admitted to the bar in 1836. During the year 1836–7 he was tutor of Latin at Yale and besides took some lectures in medicine, receiving the degree of A.M. in 1837. He then spent a year in Europe, attending lectures on natural history and medicine in London and Paris. The year 1838–39 he was at Columbia University studying with John Torrey, professor of botany and chemistry. While teaching at Western Reserve he received the honorary degree of M.D. from the Vermont Medical College and that of LL.D. from Georgetown College, Kentucky. He resigned his position in the arts college of Western Reserve in 1852, but continued to teach in its Medical School until 1856. In 1858 he succeeded Torrey in the Medical School of Columbia University and died in 1876.

For the next five years chemistry was taught by various instructors, and in 1857 J. Lang Cassels, M.D., who had been teaching in the Western Reserve Medical School, took over the course in chemistry in the arts college. Dr. Cassels was a native of Edinburgh, but had taken his medical degree in New York State. He continued to teach chemistry in the college until 1869, when Edward W. Morley, A.B., Williams, 1860, was appointed Hurlbut professor of natural history and chemistry. Up to this time chemistry had been taught wholly by means of lecture demonstrations and recitations. In 1870, however, under Professor Morley's direction a laboratory room was fitted up for students, and in the words of the catalogue from this time on "students performed under the guidance of the professor all of those experiments which were suitable for them, while those that demanded more experience were performed for the class at the table of the teacher."

After the college was moved to Cleveland additional courses were offered, and in 1892, H. P. Cushing, professor of geology and mineralogy, took over the teaching of qualitative analysis. In 1895, a full-time instructor was added in the person of Dr. Hippolyte Gruener, and in order to give Professor Morley more time to devote to research Dr. O. F. Tower joined the department in 1898. In 1906 Professor Morley[1] retired, and in 1910 a new chemical laboratory was erected and named the Morley Chemical Laboratory. In the meantime Professor Morley had been succeeded by Dr. Tower as Hurlbut professor of chemistry and by Dr. Gruener as professor in the College for Women. Since then the department has grown rapidly, and now, taking into account the department of biochemistry in the Medical School and of pharmaceutical chemistry in the School of Pharmacy, there are twenty-three professors, instructors and lecturers together with many assistants giving eighty-six courses in chemistry in the university.

In celebration of this one hundredth anniversary many of the stores of Cleveland kindly loaned some of their display windows for exhibits arranged by members of the chemical department illustrating various phases in the industrial application of chemistry.

[1] For an obituary of Professor Morley, see SCIENCE, 57: 431.

Also many of the leading chemical manufacturers in this district arranged exhibits in the chemical laboratory illustrating the industrial progress brought about by chemistry in the last one hundred years.

The culminating event of the celebration was a public address on the evening of April 12 by Dr. Harrison E. Howe, editor of the *Journal of Industrial and Engineering Chemistry* in Severance Hall, home of the Cleveland Symphony Orchestra, on "Modern Chemistry and the Next One Hundred Years." Preceding the address, the faculty of the department of chemistry entertained Dr. and Mrs. Howe at dinner at the Cleveland Club.

O. F. TOWER

APPOINTMENTS IN THE REGIONAL LABORATORIES OF THE U. S. DEPARTMENT OF AGRICULTURE

THE Department of Agriculture will make a large number of appointments in the new regional Laboratories for Research on Utilization of Farm Products as a result of examinations to be announced by the Civil Service Commission in the near future. These examinations will be held in the grades from P-2 ($2,600), assistant chemist and assistant chemical technologist, to P-5 ($4,600), senior chemist and senior chemical technologist.

Dr. Henry G. Knight, of the Bureau of Agricultural Chemistry and Engineering, calls especial attention to the significance of the fact that these examinations are the first to be held for chemists and chemical technologists in these particular grades since the establishment of the regional laboratories in July, 1938. Ever since that time the Department of Agriculture and the Civil Service Commission have been flooded with requests for information about appointments to vacancies in the laboratories. All such requests have been answered with the statement that appointments to the laboratories would be made from Civil Service registers set up by examinations to be held at the proper time.

These examinations will soon be announced. During the next two years about four hundred appointments to the regional laboratories will be made from Civil Service registers established through these new examinations. Positions will be filled requiring the services of organic, physical and analytical chemists, and others in the fields of carbohydrate chemistry, protein chemistry, oil chemistry, cellulose chemistry and chemical engineering as well as in a number of other fields. It is hoped that every person who is now interested or is likely to be interested in the future in a position in these laboratories will avail himself of this opportunity to become eligible for appointment, even though he may not be able to accept a position at the present time.

It should be emphasized that appointments in these laboratories can be made only as a result of Civil Service eligibility established through examination, and that these examinations are the ones through which the largest part of the staff of the laboratories will be selected.

All inquiries should be addressed to the United States Civil Service Commission, Washington, D. C.

THE EIGHTH AMERICAN SCIENTIFIC CONGRESS

THE Eighth American Scientific Congress will be held in Washington, D. C., from May 10 to 18. According to the official bulletin the congress has two cardinal purposes:

To advance scientific thought and achievement; to assist in celebrating the fiftieth anniversary of the founding of the Pan American Union.

Present also are the basic purposes of all inter-American meetings, namely, the examination of problems peculiar to this hemisphere and the promotion of better understanding among the American republics. It is particularly fitting therefore that this assembly of distinguished scientists and scholars should join with the Pan American Union in celebrating the completion of a half century of invaluable service to the governments and peoples of the Americas. The promotion of friendlier relations between the nations themselves may be beyond the competence of the individual scientist, but it is undeniable that the confraternity of nations is immeasurably advanced through the collective efforts of those men who, marching ever in the vanguard of civilization, maintain that science knows no national boundaries.

In a letter to Secretary of State Cordell Hull President Roosevelt writes:

Our debt to the men and women of science defies computation. The generous contributions which scholars and technicians have made to our twentieth century civilization have earned for them a position of influence and respect unparalleled in any other period of the world's history. The path of the scientist and scholar is the path to peace and prosperity which lies open to all nations and all peoples, but which unfortunately has recently been spurned by some who still cling to the archaic standards of human conduct prevalent before the very dawn of science.

It is hardly necessary to delineate here the obvious benefits resulting from a meeting of these unselfish benefactors of mankind in an atmosphere of true fraternity such as the Eighth American Scientific Congress offers. I sincerely hope that professional leaders in all the Americas will avail themselves of this opportunity to share the experiences and friendship of their colleagues throughout the hemisphere.

Dr. Alexander Wetmore, assistant secretary of the Smithsonian Institution, Washington, D. C., is secretary general of the congress, which is divided into eleven sections as follows:

Section I, Anthropological Sciences, *Chairman*, Dr. Herbert J. Spinden, curator, division of American Indian Art and Primitive Cultures, Brooklyn Museum, Brooklyn, N. Y.

ction II, Biological Sciences, *Chairman,* Dr. Edwin onklin, emeritus professor of zoology, Princeton Uni- ty; *Secretary,* James A. G. Rehn, Academy of Nat- Sciences, Philadelphia.

ction III, Geological Sciences, *Chairman,* Dr. T. Way- Vaughan, president of the Geological Society of rica, 1939; *Secretary,* Dr. Wendell P. Woodring, or geologist, U. S. Geological Survey.

ction IV, Agriculture and Conservation, *Chairman,* Hugh H. Bennett, chief, Soil Conservation Service, artment of Agriculture; *Secretary,* Ernest G. Holt, of the wildlife management section, U. S. Depart- t of Agriculture.

ection V, Public Health and Medicine, *Chairman,* Dr. mas Parran, surgeon-general, United States Public lth Service; *Secretary,* Dr. A. M. Stimson, medical er, United States Public Health Service.

ection VI, Physical and Chemical Sciences, *Chairman,* Lyman J. Briggs, director, National Bureau of Stand- ; *Secretary,* Eugene C. Crittenden, assistant director esearch and testing of the National Bureau of Stand- s.

Section VII, Statistics, *Chairman,* Dr. Stuart A. Rice, chairman of the Central Statistical Board; *Secretary,* Dr. Halbert L. Dunn, chief statistician of vital statistics, U. S. Bureau of the Census.

Section VIII, History and Geography, *Chairman,* Dr. Clarence H. Haring, professor of Latin American history and economics, Harvard University; *Secretary,* Dr. Robert C. Smith.

Section IX, International Law, Public Law and Jurisprudence, *Chairman,* Dr. James Brown Scott, trustee and secretary, Carnegie Endowment for International Peace; *Secretary,* George A. Finch, assistant secretary, Division of International Law, Carnegie Endowment for International Peace.

Section X, Economics and Sociology, *Chairman,* Dr. Harold G. Moulton, president of the Brookings Institution; *Secretary,* Benjamin Colby, Brookings Institution.

Section XI, Education, *Chairman,* Dr. Nicholas Murray Butler, president, Columbia University; *Vice-chairman,* Dr. I. L. Kandel, professor of education, Teachers College, Columbia University.

SCIENTIFIC NOTES AND NEWS

THE Franklin Medals of the Franklin Institute, ladelphia, will be awarded to Dr. Arthur H. Comp- , professor of physics at the University of Chicago, recognition "of his brilliant experiments on x-rays," to Dr. Leo Hendrik Baekeland, founder and former sident of the Bakelite Corporation, New York, for invention of bakelite. The presentation will be de on May 15.

AT the recent meeting at Cleveland of the American llege of Physicians the title of "Master" was con- red on Dr. James B. Herrick, emeritus professor of dicine at the Rush Medical College of the University Chicago, and on Dr. William Gerry Morgan, emeri- dean of the School of Medicine of Georgetown Uni- rsity, Washington, D. C. It is eleven years since the le has been awarded. The presentation was made by . Charles F. Martin, of Montreal, who is the only e living of six who previously had been so honored.

IT is announced from Villanova College that the ndel Medal, given annually to a distinguished man science who is a Roman Catholic, has been awarded Dr. Peter J. W. Debye, director of the Max Planck stitute at Berlin, who is now lecturing at Cornell niversity.

GROVER LOENING, inventor of the strut-braced mono- ane and president of the Grover Loening Aircraft ., Garden City, N. Y., has been awarded the 1940 gleston Medal of the School of Engineering of olumbia University "for distinguished engineering hievement." The Egleston Medal was founded last ar in memory of Professor Thomas Egleston, pioneer in engineering education and a member of the Columbia faculty from 1863 until his death in 1900. It is awarded annually to an alumnus who has "distinguished himself either in the furtherance of his branch of the profession, in the development of processes or of technique, or in the application of engineering principles."

DR. FREDERICK FITZHERBERT BOYCE, assistant professor of surgery in the Graduate School of Medicine of the Louisiana State University, has been awarded the 1940 Samuel D. Gross Prize for his research work on "The Role of the Liver in Surgery." The prize is offered every five years by the Philadelphia Academy of Surgery for original research work in the field of surgery. It is of the value of $1,500. By the terms of the award the material is later published as a monograph.

DR. ROBERT LEE SWAIN, of New York City, editor of *Drug Topics,* will receive the Remington Honor Medal for 1940 of the New York Branch of the American Pharmaceutical Association, in recognition of his services to the profession of pharmacy. He is the nineteenth recipient of this medal, which is awarded annually "to the individual who contributed most to pharmacy during the preceding year or whose contributions over a period of years have culminated during the year in results considered most important and advantageous to the profession."

DR. J. SAM GUY, professor of chemistry at Emory University, Atlanta, has been named to receive the 1940 Herty Award, presented annually by the Chem-

istry Club of the Georgia State College for Women for "notable contributions to the field of chemistry." The presentation will be made on May 4 in connection with the annual Herty Day exercises.

DR. HEINRICH RIES, professor of geology, emeritus, of Cornell University, has been elected an honorary life member of the Canadian Institute of Mining and Metallurgy, "in recognition of his long and distinguished service as a geologist." Recently Dr. Ries lectured at the University of Toronto on "Problems of Engineering Geology."

THE *Journal* of the American Medical Association reports that the Walter Jarvis Barlow Society of the History of Medicine has established a lectureship in honor of Dr. George Dock, since 1932 honorary professor of medicine at the School of Medicine of the University of Southern California at Los Angeles. Dr. Dock gave the first lecture at a dinner given in honor of his eightieth birthday on April 2. His subject was "A Dictionary of Medical Biography."

ACCORDING to the London *Times* the Messel Medal of the Society of Chemical Industry, London, given in alternate years for "meritorious distinction in science, literature, industry or public affairs and to one who is prominently concerned with the welfare of the society," has been awarded to Lord Samuel. The presentation will be made at the annual meeting, which will be held in London on July 9, when Lord Samuel will deliver an address.

PROFESSOR WALTER S. HUNTER, chairman of the department of psychology of Brown University, has been elected president of the Eastern Psychological Association. He was president of the American Psychological Association in 1931.

JOHN CRAIG, chairman and managing director of Colvilles, Ltd., has been elected president of the British Iron and Steel Institute. He will succeed the retiring president, Lord Dudley, at the annual meeting on May 2.

LIONEL S. MARKS, Gordon McKay professor of mechanical engineering at Harvard University, a member of the staff since 1894, will retire from active teaching next September, with the title of professor emeritus.

DR. KURT GOLDSTEIN, clinical professor of neurology at the Psychiatric Institute of Columbia University, has been appointed a member of the faculty of the Medical School of Tufts College.

Nature states that at the election meeting of the Royal Irish Academy in Dublin, it was announced that Dr. Erwin Schrödinger had been appointed professor of theoretical physics in the academy as from April 1. The funds for the professorship are being supplied to the academy by the Irish Government. Professor Schrödinger has been giving a course of lectures on wave mechanics at University College, Dublin, since November last. This course has had a large attendance from members of the two Dublin colleges. It will be continued now in the Royal Irish Academy. It is believed that the institution of this professorship is intended as a temporary measure, pending the setting up of an institute for theoretical physics in Dublin, in which Professor Schrödinger will have a permanent appointment.

PHILIP H. ELWOOD, head of the department of landscape architecture of the Iowa State College at Ames, has been appointed regional chairman for the National Resources Planning Board in charge of Region 6, which comprises the states of Iowa, Kansas, Minnesota, Nebraska and North and South Dakota. Mr. Elwood has been counselor and consultant for the region for the last six years.

THE Board of Directors of the John and Mary R. Markle Foundation has awarded to Dr. Cecil J. Watson, associate professor and director of the division of internal medicine of the Medical School of the University of Minnesota, a grant-in-aid of $3,600, in support of his studies on the significance of the excretion of various porphyrins.

THE Committee on Scientific Research of the American Medical Association has made a second grant to Dr. Fritz Schiff, of the department of bacteriology and serology of Beth Israel Hospital, New York City, to be applied toward his work on the serological classification of Salmonella.

A FELLOWSHIP in the medical sciences of the National Research Council has been awarded to Dr. Earl H. Wood, of the department of physiology of the University of Minnesota, to enable him to work with Professor A. N. Richards at the University of Pennsylvania.

DR. HARRY H. LOVE, professor of plant breeding at Cornell University, has left for Puerto Rico, where he will serve as a special adviser to the Puerto Rican Agricultural Experiment Station. He spent some time last summer making a study of the research work of the station.

DR. ARCHIBALD V. HILL, Foulerton professor of the Royal Society, whose visit to the United States has been recorded in SCIENCE, has been appointed assistant air attaché in Washington for special scientific liaison duties.

DR. J. BJERKNES, of Bergen, Norway, who, with his father, V. Bjerknes, originated the Polar Front Theory of meteorology, is now on the Pacific Coast

working under a temporary appointment for the U. S. Weather Bureau. His assignment is part of the Weather Bureau training program. He will spend one month each at airport stations in Burbank and Oakland, Calif., and Seattle, Wash., during April, May and June.

THE *Journal* of the American Medical Association states that Dr. José A. Pérez, associate professor at the University of Córdoba and director of a hospital, has leave of absence to continue his research principally on tuberculosis, in the United States at the State Health Department of New York, the Henry Phipps Institute in Philadelphia and the National Institute of Tuberculosis in Minneapolis.

DR. H. H. SHELDON, of the American Institute of the City of New York, was the representative of the American Association for the Advancement of Science at a meeting of the Iowa Academy of Science, which was held at Mt. Vernon, Iowa, on April 19 and 20.

DR. ESMOND R. LONG, director of the Henry Phipps Institute of the University of Pennsylvania, delivered the thirteenth annual William Snow Miller Lecture at the University of Wisconsin on March 25, under the auspices of Phi Beta Pi. He spoke on "The Decline of Tuberculosis with Special Reference to Its Generalized Form."

DR. JOHN A. BARTRUM, professor of geology at Auckland University College, New Zealand, who with Mrs. Bartrum is making a short visit to the United States, recently addressed students and faculty of the University of Wisconsin. His subject was "The Geology of New Zealand and Shoreline Phenomena."

SUPREME COURT JUSTICE JOHN E. MCGEEHAN, of New York, has signed the formal decree voiding the appointment of Bertrand Russell as professor of philosophy at the College of the City of New York. At a meeting of the Board of Higher Education, disregarding advice to the contrary by the corporation counsel and by Mayor La Guardia, it was decided by a vote of 11 to 6 to appeal the decision. The board has obtained the services of Emory R. Buckner and John M. Harlan as special counsel.

APPLICATIONS must be on file with the United States Civil Service Commission at Washington, D. C., not later than May 13 for the positions of associate metallurgist and of assistant metallurgist at salaries of $3,200 and $2,600 a year, respectively.

THE sixth International Congress for Experimental Cytology, which was to have been held in Stockholm from July 25 to August 1, has been postponed indefinitely.

THE American Institute of Chemical Engineers will hold its thirty-second semi-annual meeting at the Hotel Statler in Buffalo from May 13 to 15.

THE Detroit meeting of the American Association of Museums will be held on May 22, 23 and 24 and will be shared by four localities. Those who attend will be guests of the Ford Motor Company for the trips by automobile from hotel headquarters to the different meeting places. The convention will open at the Detroit Institute of Arts. There will be a general session at the institute on the first morning, luncheon as guests of the Arts Commission and sectional sessions in the afternoon followed by a trip to the Alger House branch of the institute and tea at the Grosse Pointe home of Mr. and Mrs. Edsel B. Ford. The second day will be spent at the Edison Institute and Greenfield Village in Dearborn, where Henry Ford and Edsel B. Ford will entertain for luncheon at the Clinton Inn. In the afternoon the group will be taken to Bloomfield Hills to see the Cranbrook Academy of Art and the Cranbrook Institute of Science. The third day will be spent at the University of Michigan, Ann Arbor, where the university will entertain for luncheon. The meeting will close with a dinner celebrating the twentieth anniversary of the Detroit Institute of Arts under the Arts Commission.

THE University of Rochester will hold, on May 7, 8 and 9, a conference under the general topic, "New Frontiers in American Life," as viewed by selected leaders of industrial and allied fields. This clinic is sponsored by a special committee of university trustees, and by an advisory council, of which Owen D. Young is chairman. Luncheon and afternoon sessions on each of the three days of the conference will be held at the College for Men and the College for Women, with students, faculty, alumni and guest consultants as participants. Each evening a more formal and general session will be held in the Eastman Theater of the University of Rochester. These evening sessions will be open not only to special guests, but to the public to the limit of the capacity of the theater. Some of these sessions will be of especial interest to chemists, physicists and engineers; others to business men, journalists, educators and patrons of the liberal arts.

THE Harvard Chapter of the Gamma Alpha Graduate Scientific Fraternity presented its annual symposium for the general public on the evening of April 17. Each year several speakers are invited to present special aspects of some recent scientific discovery or development, usually with emphasis placed on the varied fields of its application or on the controversial opinions concerning its importance. The subject this year, "Modern Alchemy," was concerned with radioactivity and how it may be induced and utilized. The opening speaker was Dr. J. J. Livingood, of the de-

partment of physics of Harvard University, who discussed "Atomic Nuclei and Radio-activity." Professor K. T. Bainbridge, also of the department of physics, spoke on "The Cyclotron and Induced Radio-activity." The concluding address, "Medicine and Induced Radio-activity," was given by Dr. Shields Warren, pathologist of the New England Deaconess Hospital, Boston. Later, the audience adjourned to the Gordon McKay Laboratory of Engineering, where the recently completed cyclotron was demonstrated in action.

THE seventh annual meeting of the Pennsylvania Junior Academy of Science was held recently at Washington and Jefferson College, Wasnington, Pa., with nearly two hundred and fifty boys and girls in attendance. Twenty-seven member clubs from every part of the state were represented. Caroline Emerson, Science Club of Lawrence Park High School, Erie, who spoke on "Harmful Patent Medicines," and Richard Jones, Science Club of the Johnstown Central High School, who demonstrated his Geiger-Mueller cosmic ray counter, were nominated to receive the honorary junior membership award for 1940 of the American Association for the Advancement of Science. Dr. Karl F. Oerlein, of the State Teachers College, at California, Pa., is the general chairman of the Junior Academy in Pennsylvania.

THE American Medical Association has entrusted the Committee on Therapeutic Research of the Council on Pharmacy and Chemistry with a modest fund to be expended in the promotion of investigations that may have therapeutic interest. The committee invites applications for grants in this general field, which should be in the hands of the secretary of the council, Dr. Paul Nicholas Leech, 535 North Dearborn Street, Chicago, Ill., by May 1, and which are limited to the purchase of materials or special apparatus.

THE Illinois State Academy of Science announces that it is still entertaining applications for research grants, and that awards will be announced at the annual meeting of the academy on May 3. Applicants should file their applications immediately with C. H. Behre, Jr., chairman of the Research Committee, care of the department of geology, Northwestern University, Evanston, Ill. Preference will be given to small grants intended for purchase of permanent equipment or material, and to applicants working in smaller institutions, in the State of Illinois, not liberally provided with research funds.

THE New York Academy of Sciences announces three prizes offered by A. Cressy Morrison, to be known as the A. Cressy Morrison Prizes I, II and III, which will be awarded in December, 1940. Prize I, of $500, will be awarded for the best paper on solar and stellar energy. Prizes II and III will be awarded for the best papers on a scientific subject included within the field of the academy and its affiliated societies. The competition for Prize I is open to all. Prizes II and III each of the value of $200 are limited to members, but non-members may become eligible by joining one of these organizations before the closing date.

SIXTY-SIX Canadian university students will take training in research in Canadian institutions under the National Research Council Scholarships during 1940–41. While the majority of these students will be engaged in chemical and physical investigations, such biological studies as genetics, plant pathology, physiology and zoology will each have a quota of students. Two special scholarships of $1,000 each will be held in the Division of Chemistry of the National Research Council Laboratories at Ottawa, by R. L. Cunningham and R. B. Harvey, of McGill University. Four fellowships of the value of $750 each, and thirty-seven studentships of the value of $650 each will be held at various universities directly under the auspices of the council. With the coopeoration of Canadian universities, the council is also awarding twenty-three bursaries of $250 each. The bursaries are available to students of high attainments who have just graduated and are ready to take their preliminary training in research.

DISCUSSION

THE QUESTION OF THE CELL THEORY

IN the article "The Case Against the Cell Theory"[1] which appeared in the March 15 issue of SCIENCE, the ciliate *Diplodinium* was cited as an organism that has developed systems which perform the vital functions without the "intervention" of cells. This is presented as evidence against the cell theory, yet the ciliates were stated to be monocellular organisms. If the claim had been made, as Dobell[2] and others have, that ciliates are non-cellular, there would have been clearer evidence, perhaps, to support the statement. But the simple fact that ciliates are provided with organelles that perform certain vital functions seems to be no better evidence against the cell theory than is the fact that tracheal epithelium is provided with cilia, muscle cells with myofibrils or nerve cells with axons and dendrites.

While the protozoon is a complete organism and may be compared to a higher animal as a functional being, its structure is admittedly that of a cell and

[1] B. J. Luyet, SCIENCE, 91: 252, 1940.
[2] C. Dobell, *Arch. f. Protistenk.*, 23: 269, 1911.

refore its various parts are cell-parts or organelles, d are homologues of the parts of the tissue cell, and t of the organs of a metozoon. It is true that the iate is an elaborate cell, but its specializations are ra-cellular and as such can not be homologized with tire organs or systems of the Metazoa. The tubular ectum" of *Diplodinium* is not a homologue of the tum of higher animals and therefore the word ectum" should not be applied to the ciliate organelle it is to bring about confusion of relationships. The iates swim by means of cilia, but we do not compare em structurally with the fins of fish.

The "nervous system" of the ciliate with "brain" d fibers was also compared to that of the higher imals to show that cellular organization is not neces-ry. Ehrenberg had a similar idea, but Dujardin and hers finally exploded it. Now, in the first place, the rains" of *Diplodinium* and *Euplotes*, the two classi-l examples of the neuromotorium in ciliates, have th been shown to be artifacts.[3,4] Neurofibrils hich coordinate ciliary activity are, however, present clearly demonstrable organelles. But these fibrils e also present as true homologues in the ciliated pithelium of Metazoa. Does that make ciliated epi-helium any less cellular in organization? Cell pecialization itself is in no way opposed to the cell heory.

The article further points out that chloroplastids etabolize, grow, and multiply, and therefore should e considered living units. In a sense they are living nits and the same could be said for mitochondria, entrosomes and the nucleus itself. One could also say hat the units in a brick wall are not the bricks, but he sand particles in the bricks. In none of these ases, however, are they the units of structure of the omplete organism because no possible combination of hem alone will form the whole. Just because the cell heory does not mention specifically all these cellular onstituents should we discard it? Because these cell-parts have specific functions are the cells no longer nits? Has the geneticist abandoned Mendel's princi-ples just because new complications have been discov-red which the original proposition did not fully xplain?

Lastly, if we are to distinguish cellular organization n the basis of cell partitions, we must thereby admit hat the syncytia of higher animal tissues are non-ellular as well as the plasmodium stage of Mycetozoa, tc. At the same time we must call *Amoeba proteus* ellular. Then is a binucleate amoeba cellular or non-ellular? And does a neutrophil in human blood ransform itself from a cell into a non-cellular proto-plast when one of the delicate strands connecting the polymorphous nucleus breaks? Where shall we draw the line? And will not the line be arbitrary and rather unimportant?

The "Case Against the Cell Theory" is an interesting study and has some obvious points, but are we not attacking straw men in the form of strict definitions of the cell, when we rise to demolish a theory that is thoroughly sound if a few very minor interpretations or revisions are made? We shall certainly have to make many apologies to Mr. Schleiden and Mr. Schwann if we write another theory that explains the amazing similarity throughout living organisms of their cellular (sub- or super-cellular) organization.

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[3] C. W. Rees, SCIENCE, 71: 369, 1930.
[4] J. P. Turner, *Biol. Bull.*, 64: 53, 1933.

"ELECTRICITY ELICITED BY AN ORGANIC CHEMICAL PROCESS"

UNDER this title Berzelius, in 1817, described the discharge of electric organs. He based his assumption on the fact that the organs have no resting current and that the discharge here is a voluntary process, in contrast to the ordinary electric pile.[1]

Electric organs have been compared with an accumulation of muscle end plates. When, at these end plates a concentration of choline esterase was found, as high as necessary to admit that acetylcholine might be involved in transmission of motor nerve impulses[2] a similar mechanism was envisaged for the action of the nerves supplying the electric organ. A concentration of choline esterase of the same order of magnitude as calculated for motor end plates was found in the electric organ of Torpedo.[3,5] 1 g organ splits 1.5–3.0 g acetylcholine in 60 minutes.

In contrast to this high concentration of the enzyme, that found in the electric organ of *Raja* which has a weak electromotive force is low: 1 g organ splits only 0.03–0.1 g acetylcholine in 60 minutes. 1 g of the powerful electric organ of Gymnotus splits 0.9–1.5 g acetylcholine.

If the electromotive force of these organs per cm of tissue (in the direction of the current) and the number

TABLE I

	Volt per cm	Plates per cm	Q.Ch.E.*
Raja	0.5	15	3–10
Gymnotus	5–10	60–80	90–150
Torpedo	8–15	100–200	150–300

* Q.Ch.E. = mg acetylcholine hydrolysed by 100 mg tissue in 60 minutes.

[1] J. J. Berzelius, *Laerbook i Kemien.*, 1: 126, 1817.
[2] A. Marnay and D. Nachmansohn, *C. R. Soc. Biol.*, 124: 942, 1937.
[3] A. Marnay, *C. R. Soc. Biol.*, 126: 537, Paris, 1937.
[4] D. Nachmansohn and E. Lederer, *C. R. Soc. Biol.*, 130: 321, 1939.
[5] D. Nachmansohn and E. Lederer, *Bull. Soc. Chim. Biol.*, 21: 797, 1939.

of electric plates per cm is compared with the enzyme concentration an interesting parallelism is found. The comparison is given in Table I.

In view of the difference in structure, size and arrangement of plates it is desirable to compare also the maximal discharge and the number of plates in series at such a discharge with the total amount of acetylcholine which can be split by the different organs. This is given in Table II.

TABLE II

	Number of plates in series	Maximum discharge in volt	Mg A.Ch. split by organ in 1 second
Raja	60–80	1–3	0.5–1.0
Torpedo	400–500	30–60	50–100
Gymnotus	5000–6000	300–800	500–1000

The concentrations of choline esterase found in electric organs suggested the cholinergic nature of the nerve supplying the organs. Recent experiments have brought further support for this assumption showing liberation of acetylcholine from the electric organ during stimulation of the nerve and the possibility of eliciting a discharge which is here the terminal event by injection of minute amounts of acetylcholine.[6]

The observations lend support to the concept which Berzelius formulated more than a century ago and apparently not noticed since then.

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AGAIN SCIENCE IN CHINA

RECENTLY a letter appeared in SCIENCE (March 8, 1940) describing some of the difficulties under which the Chinese scientist must work. Almost simultaneously the following plea came to my desk as secretary of the Union of American Biological Societies. Believing that there are many individual biologists as well as departments willing to send reprints and other scientific publications to the National Central Library, the original plea, signed by Chiang Fu-tsung, librarian of the National Central Library, outlining the situation, and giving the necessary instructions, is printed below.

With a view to supplying our science students with scientific publications to further their research, the National Central Library takes pleasure in soliciting your assistance and cooperation in the rebuilding of its collections by sending us your publications. Your courtesy and action in putting our name on your free mailing list will be highly appreciated by the Chinese people at large.

Word has it that assistance rendered at its time of great need will forever stand in the memories of those individuals who are craving for help. Owing to our hurried departure from Nanking, more than 200,000 ... umes fell into the hands of the Japanese, who set the... together with the valuable collections of other insti... tions, on fire. With the bombing of Chinese educatio... institutions by Japanese airplanes, the destruction ... Chinese culture is thus made complete. However, th... library has managed to transport a large portion of ... holdings out of Nanking to Chungking, the provisiona... capital. As a result, there are tens of thousands ... students and scholars in China who are entirely devo... of means to advance their studies. Facing this intell... tually hungry lot, it is my crusading responsibility a... pleasure to write for complete sets of your publicatio... to be made accessible in this library. Through a syst... of mail services, books thus acquired will be sent to a... individual for stated periods in any part of free Chi... Your publications will be placed in our Chungking bran... library building, which is now nearing completion.

In sending us your publications, please send them b... book post *via* Haiphong, French Indo-China.

GEORGE W. HUNTER, III

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THE PROGRAMS OF SCIENTIFIC MEETING...

HAVING attended a number of the meetings of th... American Association for the Advancement of Scienc... held at Columbus, I wish to make two protests.

In the first place, it seems a waste of time on th... part of any intelligent person to spend two hours pe... session listening to the reading of papers with litt... opportunity for comment. One and a half minute... per paper was the average time allowed in meeting... I attended. Apparently the purpose of the meeting i... not the advancement of science but the reading o... papers. If the persons presenting papers knew tha... as many minutes would be spent in the discussion o... papers as in their reading, the quality of the paper... presented as well as the participation of the audience... might be greatly improved.

In the second place, it certainly is a reflection on a... learned profession when its representatives, selected... as members of the panel set up to discuss the issues o... a paper presented by a principal speaker: (a) ignore... the issues; (b) give ten-minute prepared speeches com... posed in most part of personal anecdotes; (c) meet... questions from the floor by "name calling"; (d) exhibit... "authoritarian" attitudes toward "status" rather than... "experimental" habits of mind.

I realize the difficulties involved in setting up panel... discussion meetings. It seems, however, that a little... more careful preparation on the part of participants... plus a disposition to promote "attitudes of inquiry"... rather than "smug acceptance of present practice"... would be more in keeping with the purposes of a... scientific body.

C. B. MENDENHALL

THE OHIO STATE UNIVERSITY

[6] W. Feldberg, A. Fessard and D. Nachmansohn, *Jour. Physiol.*, 97: 3 p., 1940.

REPORTS

PURE AND APPLIED SCIENCE RESEARCH AT MELLON INSTITUTE, 1939–40

NINETY-ONE industrial fellowships—31 multiple and individual fellowships—have been active in Mellon stitute during its fiscal year, March 1, 1939, to March 1940. These programs of research have employed 7 fellows and 106 fellowship assistants. The instite has expended $1,181,639 in conducting these investations and comprehensive studies in pure science this period, during which much new fundamental search has been begun by industrial fellowships and re science investigation has been considerably exnded. These research projects and their accomplishents are described in the twenty-seventh annual reort of the director, Dr. Edward R. Weidlein, to the nstees of the institution.

In the Department of Research in Pure Chemistry vestigations of cinchona alkaloids in relation to the emotherapy of pneumonia have been continued on a ider scale. In the light of the experimental findings the medical associates working with homologous and omeric alkyl and hydroxyalkylapocupreine ethers, a stematic study of variously substituted two-and-ree-carbon ethers is now in progress, and a series of aternary salts of hydroxyethylapocupreine has been repared and tested. While hydroxyethylapocupreine as been in constant medical use, no new clinical exeriences have been published since the three-year mmary presented last year. In a preliminary way has been found that the synthetic cinchona derivaves have powerful bactericidal action against organms of other groups than the pneumococcus. Sixty-ne new preparations have been tested against the neumococcus. The production of hydroxyethylapoupreine on a pilot-plant scale has been continued very uccessfully, and studies of methods and processing ave permitted some simplification. Adequate availbility of the drug has been assured for large-scale ooperative clinical investigations already organized.

Chemotherapeutic and immunological approaches to he study of pneumococcal and streptococcal infections ave been continued with the aid of Mellon Institute n the Institute of Pathology of the Western Pennylvania Hospital by a staff of eight. A number of erivatives of sulfanilamide have been examined for heir therapeutic value, dosage, and toxicity, and it as been found that all these drugs are at least as effective as sulfanilamide and that certain of them ause in experimental animals the same type of urolithiasis reported in clinical practice. Additional research on the mode of action of the sulfonamide compounds has reinforced the anti-enzymatic theory previously postulated by this group which tends to explain the diversity of the therapeutic coverage of sulfanilamide. Other studies have pertained to the antigenic and serologic relationships of various dissociated bacterial forms in an effort to coordinate these fundamental interrelations with the diverse manifestations of disease in man and animals. The work on factors predisposing to infections of the type encountered in pneumonia and the common cold has been extended.

The nutrition fellowship of the Buhl Foundation has advanced the study of nutritive factors in relation to dental caries. Particular attention has been given to the beneficent effects of fluorine in the partial prevention of tooth decay. The data, derived from rats, indicate that, if there is a deficiency of fluorine at the time of formation of enamel, the caries-resistance of the teeth is lowered. In view of this evidence and the findings of other investigators, it has been urged by fellowship that consideration be given to the possibilities of the mass reduction of dental caries incidence by control of the fluorine content of community water supplies. The toxicity of fluorine must not be forgotten in any measures to alleviate dental caries.

Basic research, a prerequisite of progress in industrial hygiene, has been supported by Air Hygiene Foundation at Harvard School of Public Health, the Saranac Laboratory, University of Pennsylvania and Mellon Institute, where the organization has its headquarters. At Harvard two graduate fellows carry on engineering studies of value to companies associated with the foundation. In turn this arrangement helps train able men for the service of industry and government in the comparatively new field of industrial hygiene. Two broad investigations are sustained by Air Hygiene Foundation at the University of Pennsylvania. One of these researches deals with x-ray and seeks to place diagnostic procedure on a more practical basis for use in industrial plants, as in the physical examinations of large groups of workmen. In the other project at Pennsylvania the actual effect of silica on living cells and tissues is being observed. At Mellon Institute the foundation has a clearing-house for all its day-to-day activities, assisting in the correlation of data indispensable to the advancement of industrial hygiene. For instance, more and more regulation is being exercised by government in the field of occupational health. Obviously it is imperative that employers be kept informed of new laws pertaining to employee health. This work the foundation does for its member companies through its legal committee. The foundation has launched a survey of sick absenteeism among industrial workmen. This report on the high cost of sickness was submitted to

foundation members at their fourth fall meeting late in 1939. On that occasion cost figures were presented to show that "good health is good business"—a translation of industrial health into terms of dollars-and-cents. A forum was held at the meeting which helped clarify the concept that industrial health pays double dividends: first, in dollars and cents; secondly, in improving industrial relations and public good-will, the very basis of business. During 1940 the foundation program will include continuation of the researches mentioned. It will also embrace: (1) Further study of sick absenteeism, looking toward reducing the staggering "hidden" losses which employers and employees suffer from this cause; (2) an industry-wide engineering survey of existing exhaust systems, many of which are now inadequate, for the purpose of assisting member companies to cope with problems in this field; and (3) expansion of the foundation's industrial hygiene surveys which are made for member companies. A special bulletin on the subject of organic solvents as they relate to the problem of industrial health will soon be published. Each month the foundation issues a digest of the current literature on industrial hygiene.

The pearl fellowship continued to seek by chemical and physical methods additional data on pearls and mother-of-pearl. X-ray powder photograms of natural pearl aragonite and natural crystalline aragonite have shown that the two forms of orthorhombic calcium carbonate are fundamentally identical in structure. For quick, accurate determination, in which many pearls can be examined at one time, the x-ray fluorescent method is exceedingly useful. The cause of the fluorescence of cultured and fresh-water pearls has been found to lie in the chemical composition.

As a result of investigations carried out by the chain fellowship, the donor has been able to announce the development of several types of arc welding electrodes formerly not included among its products. Recognizing the potentialities of powder metallurgy and the need in this field for a high quality iron powder, methods have been perfected by another fellowship for the preparation of electrolytic iron powder. Since 1934 sub-commercial activities have been carried on progressively at the donor's plant, and as a result many industrial applications for this pure iron powder have been established and early commercialization of the procedure on a large scale is expected. During the second year of the acid recovery fellowship the survey being made of the waste pickle liquor problem has been extended to include studies of twelve methods of disposal without by-product recovery and forty-two processes for the treatment of the liquor with recovery of by-products. Marked improvements in three older processes and laboratory investigations of two newly proposed processes have been reported during the year.

The multiple fellowship on organic synthesis is in its twenty-sixth year of research on problems pertaining to the preparation and use of synthetic organic chemicals. During the year 1939–1940 the fellowship has followed its policy of developing new products on an experimental scale and studying their possible applications in industry. New uses for products already available have also been investigated in an effort to broaden their markets. Work was continued on problems pertaining to hydraulic fluids, gas purification and dehydration, alkyl silicate coatings, improved wood-stain solvents, evaluation of and improvements in wetting and dispersing agents, water-soluble lubricants, volatile inhibitors, and new amine products. The chemical hygiene fellowship has obtained during its first two years experimental data on some of the physiological properties of over 100 synthetic organic compounds, most of which had not previously been studied pharmacologically. It is the aim of the fellowship to detect any hazards in handling these compounds, so that adequate protection of workmen can be planned in advance of exposure. Its further object is to determine the safety of suggested applications of the compounds, from studies of their physiological properties. The greatest need for facts is in the field of vapor effects.

In 1939 the fellowship on meat merchandising described a new and rapid method for the tendering of edible flesh. Following the completion of consumer acceptance tests in Pittsburgh, during which a series of eight stores distributed the novel Tenderay beef to their customers for periods ranging from three to eight months, a commercial plant was installed in Cleveland, having a weekly capacity of 60,000 pounds of beef and supplying 78 stores. From a store average of about 600 pounds per week there has been an increase, in ten months, to approximately 1,000 pounds per week, a gain of over 60 per cent. In order to care for all the stores operating in the Cleveland district, the plant has been enlarged to provide approximately 110,000 pounds per week. A second company plant was completed in Cincinnati during February, and plants in Chicago, Columbus and Detroit are ready to begin operations. An independent packer on the eastern seaboard started production of a Tenderay plant in February, another firm has a plant under construction in the Middle West, and plans are being drawn for four additional plants. It is estimated that by June 1 plants in operation will be tendering three million pounds per week. The multiple fellowship on food varieties perfected recipes for and brought to the stage of commercial production three new desserts in the donor's line of junior foods. Another new variety in the strained foods line was developed and put into production. Research on the calcium availability of

strained foods has proceeded far enough to indicate marked differences in the utility of the calcium contained in them. The fellowship has cooperated in the development of new uses in the food field for edible cereal cellulose.

The multiple fellowship on mineral products continued work on by-product silica from plate-glass manufacture. The practicability of the use of Garspar, one of the products of fellowship research, to replace coarse sand and cullet in a glass batch was proved. On the fellowship on optical glass research on the durability of experimental glasses has been made the basis for the development of improved optical glass. The study of chemical reactions that can take place between a glass surface and different reagents has eventuated in the selection of methods by which the outer polished surface of a lens may be changed without affecting the mass of the glass.

On the multiple fellowship on sulfur a number of new projects have been studied in the laboratory in preparation for commercial introduction. Two novel materials, evolved through the reaction of sulfur with organic compounds, are now receiving pilot plant-scale development. The physical nature of sulfur cements has been constantly under study and recently methods of evaluating sulfur cements have been reviewed in assistance to the American Society for Testing Materials. For the multiple fellowship on protected metals the cupriferous cement Hubbellite has shown good performance for floor surfaces. The outstanding property of this cement results from the oligodynamic action of the copper compound in it. Hubbellite provides simply by washing a self-sanitizing floor that does not depend upon the use of disinfectants. The same fellowship has devised a fireproofing system, involving the use of a new plaster composition (expanded vermiculite aggregate and gypsum), by means of which fire-resistive periods have been attained that are far in excess of those heretofore possible wtih comparable weights and thicknesses of accepted materials.

In research by the multiple fellowship on anthracite greenhouse and field tests have shown the value of Pennsylvania anthracite ashes for soil-amendment purposes. Work has also continued on the uses of anthracite ashes and colliery refuse for industrial purposes, especially in the fields of building materials and thermal insulation. During the past year the fellowship published a full testing procedure for water heaters fired with solid fuels, and completed an engineering study of the design of anthracite bins for both automatic and hand-fired appliances. The multiple fellowship on petroleum refining has been pursuing work on examining petroleum oils by micro-methods. A thoroughgoing fundamental study of the constitution of certain lubricating oils and a previously initiated investigation on determining the physical properties of mineral and vegetable waxes have been continued, as also have been studies of refining methods for gasoline and of procedures for protecting petroleum products against harmful oxidation. The prototype engine testing work, aimed at a better knowledge of combustion engine deposits, has been conducted actively. It has been possible to establish clearly some of the fundamentals of the phenomenon known as oil-ring clogging and to point out its meaning in connection with engine-oil consumption. The fellowship on watch technology has progressed toward the development of the ideal watch oil. A large number of compounds have been synthesized, and properties vital to the quality of a watch and instrument lubricant have been determined. The ninth and tenth years of the safety fuse fellowship have been devoted to basic research on the waterproofings used on fuses with the object of improving the present products and of obtaining accurate knowledge of the domestic supply of petroleum asphalts. The properties of asphalts made from crudes produced in major American oil fields have been determined; several of these asphalts yield satisfactory waterproofing coatings.

The program of investigation on new uses for cotton and its by-products, established by the Cotton Research Foundation in 1937, has been followed creatively. The subjects of research include not only problems of immediate practical importance, but also long-range fundamental studies which will contribute basic information on the chemistry and physics of the various products derived from the cotton plant. Eight scientists are engaged in this work at the institute, and four universiy research grants are in operation. During the year the fellowship has benefited from the sponsorship of the National Cotton Council, for which the Cotton Research Foundation is now serving as the technical agency. Researches on the physical and mechanical properties of the cotton fiber are being prosecuted constantly. The knowledge that has been obtained in this basic study is being applied successfully to practical problems, particularly in the use of cotton in tire cords and similar industrial products. The possibility of employing lower grades of lint, linters, and hull fiber in the manufacture of finer grades of paper is being accorded research. Contributions have stimulated considerable interest in the wider utilization of hulls, an abundant cotton by-product. Cottonseed proteins, particularly the globulin, have received much attention by the fellowship.

Thirteen fellowships started their researches during the fiscal year 1939–40: Concrete, Constructional Resins, Gartex, Gas By-products, Gas Purification, Graphite, Metalworking, Oil Cleaner, Sterilamp, Suture, Tar Distillation, Tar Synthetics, and Tar Treatment. Another new fellowship (Petrolatum) began operation in March. Six fellowships concluded

their investigations: Calgonizing, Chromium, Cotton Yarns, Draft, Slag, and Tar Acids.

During the calendar year 1939, 7 bulletins, 26 research papers and 54 other articles came from the institute. Thirty-two United States patents and 35 foreign patents on fellowship inventions proceeded to issue. The total publications for the 29 years ended December 31, 1939, have been 18 books, 140 bulletins, and 1,734 journal contributions; 755 United States patents and 811 foreign patents were granted during the same period. Bulletin No. 4 in the institute's bibliographic series, which was published in the fall of 1939, lists the books, bulletins, journal contributions, and United States and foreign patents of the institutional membership, 1911–1938, inclusive.

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SPECIAL ARTICLES

FACTORS AFFECTING THE INSULIN CONTENT OF PANCREAS

IN 1939 Best, Haist and Ridout[1] reported that fasting or feeding fat produced a fall in the insulin content of pancreas of rats and that the subsequent provision of a balanced ration led to the restoration of the insulin level to normal values.

Similar experiments have been carried out in hypophysectomized rats. The insulin content of the pancreases of rats 26–66 days following the removal of the pituitary glands was slightly less than that of intact animals fed *ad libitum*, but did not significantly differ from that of control animals receiving the same caloric intake. The average values obtained were 20.4 units of insulin per group of 10 rats for the hypophysectomized animals and 20.1 units of insulin per group of 10 rats for the "paired-fed" controls.

Feeding fat for one week to hypophysectomized rats led to a fall in the insulin content of pancreas in those which survived. This decrease was slightly greater than that of the control group. Feeding a balanced diet for 7 days to hypophysectomized rats previously fed fat for one week led to the restoration of the insulin content of pancreas to normal values.

These experiments demonstrate that the lowering of the insulin content of pancreas as a result of feeding fat and the restoration to normal as a result of feeding a balanced diet can be obtained in hypophysectomized rats. It is suggested that the production and liberation of insulin, according to the need for it, can be regulated by the pancreas in the absence of the pituitary gland.

We have recently found that partial pancreatectomy in dogs produces no change in the insulin content of the pancreas unless enough pancreatic tissue has been removed to cause diabetes. In this case the insulin content shows a marked decrease.

The daily administration of insulin to fasted rats decreases the insulin content of the pancreas to levels appreciably lower than those secured by fasting or fat feeding alone. These findings, considered in conjunction with histological results, suggest that the β cells of the islets of Langerhans are "rested" by fat feeding, fasting and insulin administration.

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[1] C. H. Best, R. E. Haist and J. H. Ridout, *Jour. Physiol.*, 97: 107, 1939.

TOXICITY OF EXTRACTS OF THE POSTPARTUM RABBIT UTERUS[1]

IT is unusual that crude saline extracts of a tissue are toxic on administration to animals of the same species. Extracts of the postpartum rabbit uterus, however, taken one to fifteen hours after delivery, were found to be extremely toxic to normal rabbits.

In some unpublished data obtained in this laboratory, it was observed that the uterus of the pregnant rabbit becomes markedly edematous two to three days before delivery, and that this edema slowly recedes during the next six to eight postpartum. Four different, crude, saline extracts were made from such edematous uteri, taken within fifteen hours after delivery. These were prepared so that 1 cc of solution represented one-half gram of tissue. They were then injected into a total of 15 animals. Death resulted within 2 minutes in 12 animals on intravenous injection of 8 cc or less. Of the remaining two animals, one survived a 10 cc injection but succumbed on the following day after administration of an additional 1 cc. The second animal survived a 10 cc injection but also died on the next day after being given an additional 4 cc.

These extracts were also toxic when administered intraperitoneally, although a large dose was required and a longer time elapsed before death occurred. Three animals injected by this route were given three daily doses of 10 cc and each succumbed after receiving a total of 30 cc.

Extracts prepared in the same way from uteri of non-pregnant animals were not toxic. Four such extracts were injected intravenously in daily doses of 10 cc until two animals each received a total of 50 cc, a

[1] Aided by a research grant from the University of California.

third 60 cc, and a fourth received 70 cc. These animals exhibited no ill effects from this treatment. Also, extracts of liver and of muscle from postpartum animals were without effect even though extracts of edematous uteri from the same animals were strongly toxic.

Since a postpartum rabbit uterus contains a toxic factor when administered to normal animals, it was considered possible that a postpartum rabbit with its edematous uterus intact would be less susceptible to uterine extracts known to be toxic than would a non-pregnant animal. To this end, extracts of known toxicity were injected into four rabbits, two on the day before delivery, a third on the day of delivery, and the fourth, one day postpartum. Death occurred in all of these after injections of less than 8 cc, indicating that these animals were no less sensitive to the toxic factor than were non-pregnant animals.

The symptoms immediately preceding death in all these animals were strikingly similar to those described in anaphylaxis, although none of the animals used had been previously sensitized. Autopsy of four animals indicated that the pathological changes also were similar to those found after anaphylactic death. The similarity in both symptoms and pathological changes to those of anaphylaxis, and the reported relation between anaphylaxis and histamine suggest a possible explanation for the toxicity of saline extracts of postpartum uteri. Experiments now under way indicate that the presence of large amounts of histamine or a histamine-like substance may be responsible for the toxicity of such extracts.

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THE BIOLOGICAL ACTIVITY OF SYNTHETIC PANTOTHENIC ACID

FOR some time we have been interested in the chick antidermatitis factor content of rice bran filtrate ("Vitab" Type II), which has been demonstrated to be a rich source of this vitamin.[1] In this connection the recently reported determination of structure and synthesis of pantothenic acid by Williams and Major in SCIENCE[2] is of considerable interest. Since a microbiological method for the estimation of this factor is available,[3] rapid methods of assay are at hand to further the chemistry of pantothenic acid, which is regarded as identical with the chick anti-dermatitis component of the B complex.[6] We have synthesized β, β-dimethyl-α-hydroxy butyrolactone, condensed it with β-alanine and measured the activity of the product microbiologically. Representative results are presented in Table 1.

TABLE 1

COMPARATIVE MICROBIOLOGICAL RESULTS BETWEEN "VITAB" TYPE II RICE BRAN FILTRATE AND SYNTHETIC PANTOTHENIC ACID

cu mm rice bran filtrate	cc N/10 acid above blank	cc. diluted sample synthetic pantothenic acid	cc N/10 acid above blank
0.05	1.0	0.5	1.7
0.1	2.2	1.0	2.9
0.15	2.8	1.5	4.1
0.2	3.6	2.0	5.0
0.3	4.7	3.0	6.7
0.5	5.5	5.0	7.4

The crude synthetic product was assayed at a level of 0.28 micrograms per cubic centimeter. This may be compared with the pantothenic acid content of rice bran filtrate ("Vitab" Type II), which is indicated to be 20–27 "filtrate factor units" per gram.[1] This corresponds to approximately 0.4–0.5 milligrams of pantothenic acid per cubic centimeter. Since 0.28 micrograms of the crude synthetic product (1.0 cc diluted sample) stimulated the production of the same amount of acid as 0.15 cu mm of rice bran filtrate supplying .06–.075 micrograms of pantothenic acid, the yield of pantothenic acid was approximately 25 per cent. If the unnatural isomer is inactive, however, the yield was approximately 50 per cent.

On the basis of the above comparative data, it is seen that good agreement was obtained between the expected values for the biological activity of pantothenic acid as supplied by rice bran filtrate and the crude synthetic product. These results agree substantially with those of Woolley,[7] who utilized "partially synthesized" pantothenic acid. In any case it is evident that significant biological activity resulted when our synthetic pantothenic acid was assayed by the microbiological method.

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[1] T. H. Jukes and S. Lepkovsky, *Jour. Biol. Chem.*, 114: 109, 1936; T. H. Jukes, *Jour. Biol. Chem.*, 129: 225, 1939.

[2] R. J. Williams and R. T. Major, SCIENCE, 91: 246, 1940.

[3] The microbiological method of assay was made available to us through the courtesy of Dr. R. J. Williams in advance of publication. It is a modification of the Snell and Strong procedure for the estimation of riboflavin (see footnote 4) and was presented at the meetings of the Society of Biological Chemists, New Orleans (see footnote 5).

[4] E. E. Snell and F. M. Strong, *Ind. Eng. Chem., Anal. Ed.*, 11: 346, 1939.

[5] E. E. Snell, D. Pennington and R. J. Williams, *Proc. Soc. Biological Chemists*, New Orleans, 1940.

[6] D. W. Woolley, H. A. Waisman and C. A. Elvehjem, *Jour. Am. Chem. Soc.*, 61: 977, 1939; T. H. Jukes, *Jour. Am. Chem. Soc.*, 61: 975, 1939.

[7] D. W. Woolley, SCIENCE, 91: 245, 1940.

SCIENTIFIC APPARATUS AND LABORATORY METHODS

IMPROVEMENTS IN THE HARVARD SPRING KYMOGRAPH

THE Harvard kymograph, which is used so generally in physiology laboratories, ordinarily requires frequent adjustments which can be avoided to a large extent by a few minor alterations.

Constant tension of spring clip for drum: Cut off three eighths of an inch from the free end of the clip (A, Fig. 1). Bend clip downward 100° one fourth

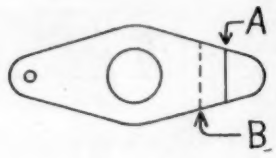

Fig. 1

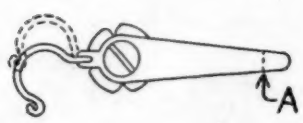

Fig. 2

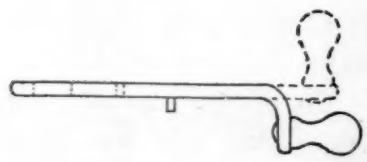

Fig. 3

inch from the cut end (B, Fig. 1). This allows the free end of the clip to move about three sixteenths of an inch when mounted on the drum. Tension, once adjusted, remains constant.

Brake: Bend the end of the brake arm one fourth inch from the end downward 90° (A, Fig. 2). Adjust brake shoe so that braking occurs when arm is moved to the right as far as possible. Brakes so adjusted require no attention for years.

Winding lever: Bend the winding lever downward 90° one half inch from the free end (Fig. 3). This places knob in a horizontal position on the side of the kymograph and prevents interference with the rotating vane.

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A PLASTIC COVER GLASS, ISOBUTYL METHACRYLATE

EITHER Canada balsam or gum damar, long used media for cementing covers over tissue sections, have the objection of taking days to harden sufficiently to permit cleaning and may turn yellow in time.

Nevillite, or Clarite, as recently suggested by the General Biological Company, dries rapidly and is practically without color.

We have recently found that another plastic, isobutyl methacrylate, dissolved in benzol or in xylol is a water-white solution, dries hard in from five to ten minutes and results in a mounted preparation that is somewhat more brilliant when viewed under the microscope than are specimens mounted in Clarite. The refractive index is given as 1.477, almost exactly that of glass.

Isobutyl methacrylate may also be used to replace the cover glass. A stained section on a slide when dipped into a thin solution of this plastic, withdrawn carefully so that the solution drains evenly from the slide, will be so coated as to protect it with apparently the same adequacy as does the usual cover glass. The coating on the back of the slide may be allowed to remain or can be removed with a cloth moistened with benzol or xylol.

The thinness of this coat will interfere less with the transmission of light than does a cover glass. Immersion oil does not dissolve it and the film can be washed in alcohol and polished with a paper handkerchief. The film will scratch, but these scratches can be removed by dipping the slide into the solution of the plastic.

This film can be written on with ordinary ink. Or a label can be written directly on the glass and then dipped, for protection, into isobutyl methacrylate. The quick drying characterisics of this new solution may make it useful in filling up deep well mounts. The crystals sell for about one dollar a pound. It was originated by the du Pont Company.

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